THE PHYSIOGRAPHY OF THE SHOALHAVEN RIVER VALLEY. II.

Nerrimunga Creek.

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(Plates xii–xiii; four Text-figures.)

[Read 24th June, 1931.]

Foreword and Acknowledgments.

This paper extends the area considered in the first of the series, and embraces an area of country lying to the west of the Shoalhaven River. No physiographic work had previously been undertaken in the area drained by Nerrimunga Creek and its tributaries, but means of communication by means of roads and tracks are good, and only the more dissected parts present any difficulties of access. The writer wishes to thank Mr. and Mrs. G. McKane, of Windellama, for their hospitality during the course of fieldwork. Mr. McKane also acted as guide on occasions, and his intimate knowledge of the country was of great assistance to the author.

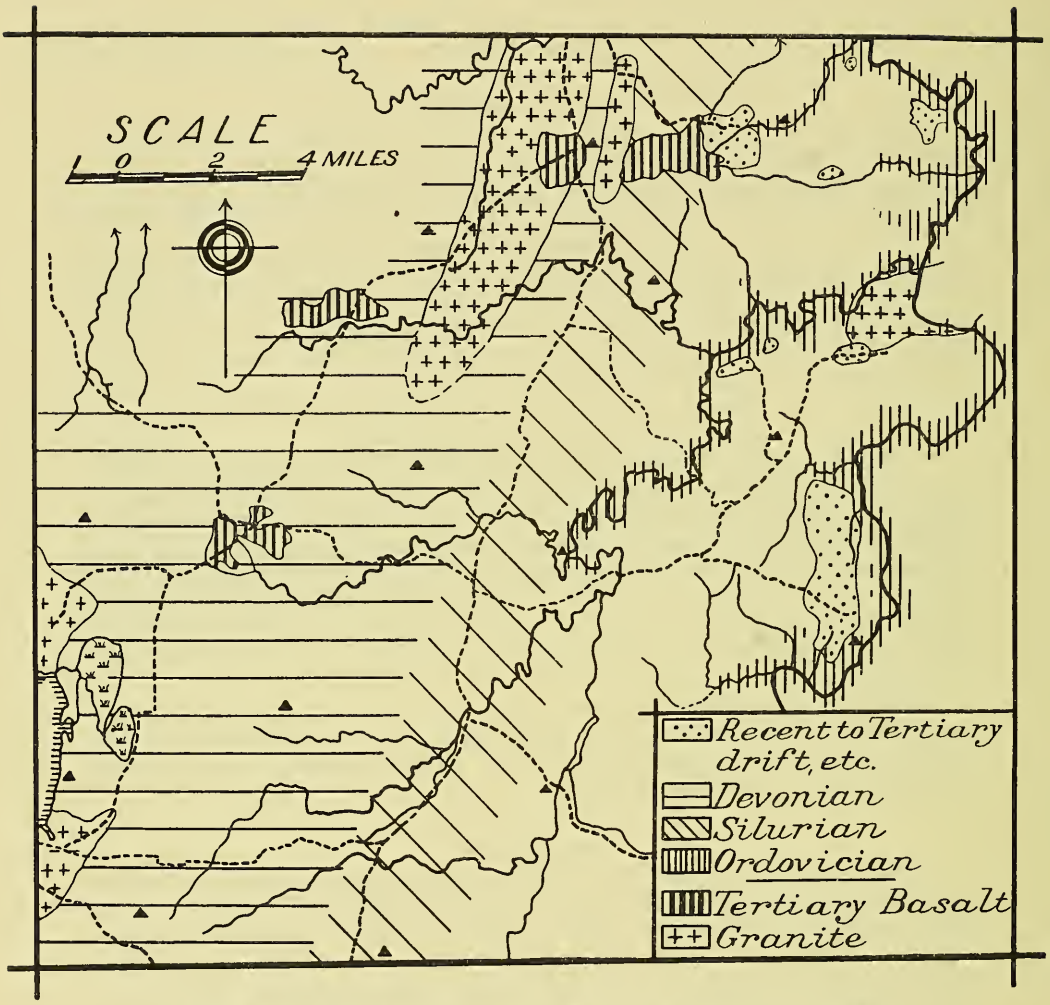
Maps used in connection with the work were given by the Lands Department, and formed an admirable basis for topographic work. The magnetic meridian (declination 9° 35′ E.) is used throughout the paper and, unless otherwise stated, all heights are in feet above sea-level.

Area Dealt With.

The area shown in Plate xiii is some 285 square miles, of which the greater part is drained by Nerrimunga Creek. There is no extensive occurrence of horizontal rocks over this district, which is formed essentially of folded sedimentary and metamorphic rocks which, being closely bedded and well jointed, favour the development of an undulating plain topography in areas of mature erosion. The greater part of the country here considered comes within this class, exceptions being provided by the gorges towards the east and higher residual hills and ridges on the western divide. The absence of the peneplain at 2,200 feet, so extensively developed to the north-east, may be directly correlated with the approximate absence of horizontal strata, and is a characteristic shared by the country further south.

General Geology.

Little is known of the geology of this area, and the boundaries of the various formations have not been determined. Devonian strata are known to exist over its western section, marine fossils of middle or upper Devonian age having been found at Tarago (*fide* W. S. Dun), but their eastern boundary is quite uncertain and they are supposed to grade into strata of Silurian age which, in turn, rest upon highly folded and metamorphosed Ordovician beds. The whole problem is



Text-fig. 1.—Geological Sketch of the Area. The divisions must be taken as broad generalizations only. (After official State map of 1914.)

greatly obscured by great surface weathering in all places except the newly-eroded gorges, and by the accumulation of rock waste over the eastern part of the area. For the purposes of this paper, a general classification can be made under the headings "metamorphic" and "sedimentary".

a. The Metamorphic Series.—The Ordovician beds observed near Tallong continue southward, and their strike swings to 30 degrees east of magnetic north in places along Nerrimunga Creek. In the gorge of the Shoalhaven, erosion has revealed considerable lateral movement so that, for short distances, the strike is almost east and west. The principal rock types observed are grey slates, quartz-schists and massive quartzites. The latter especially are intersected in places by great numbers of quartz veins. At higher levels the highly metamorphosed

character of these strata becomes modified, and bedding and joint planes become more closely spaced, rendering erosion an easier matter.

These strata extend between Nerrimunga and Cowhole Creeks, in both of which there are some fine exposures. On the south of the former stream the rocks of the tableland surface consist of sandstones, shales and, in places, slates, but these are often obscured by surface deposits of clay, sand and grit. It is probable that these relatively unaltered sediments belong to the same series as the metamorphic strata in the gorges, but this is not certain over the whole area involved. (See also Woolnough, These PROCEEDINGS, xxxiv, 1909, pp. 783-84, for a similar case at Tallong.)

Towards the western part of this section of the area, especially along the meridional course of Nadgigomar Creek, a zone of coarse sandstone is found which varies in colour from brown to white and light grey. It is penetrated by numerous narrow and irregular quartz veins, and towards Nerrimunga Creek it would appear to pass directly into the grey quartzites. A similar state of affairs exists elsewhere in the Shoalhaven Valley (see No. iv of this series, on Nerriga district, when published). East of the sandstone a series of white chert is found which forms much of the eastern divide of Nadgigomar Creek. It is suggested that the sandstone referred to is on the western periphery of the Ordovician beds, which underlie newer rocks to the west (Text-fig. 1).

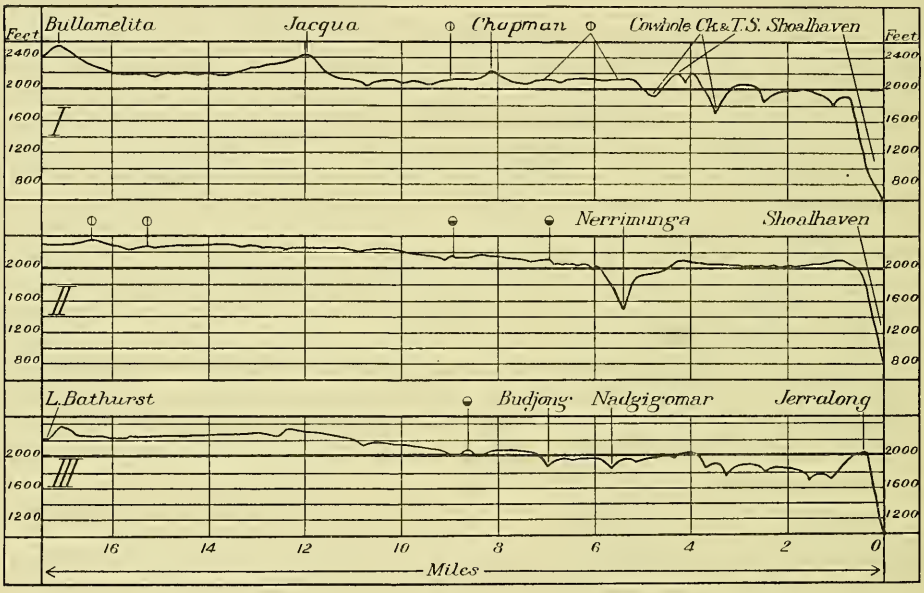
With the exception of a belt of country extending southward past Blanketburn Trig. station, in which the sedimentary strata are in the form of a gentle syncline, rocks in the eastern part of the area dip steeply owing to intense folding. This is especially the case in the lower levels of the gorges. Physiographically, the differential hardness of the various strata is not of first-rate importance, as the hardest occur below the level of the tableland. Greater powers of resistance to erosion have led to the survival of such sections as that forming the Cowhole Trig. station ridge, whilst softer sedimentary rocks on the tableland surface have weathered deeply, and have been subjected to considerable local erosion in places.

b. The Sedimentary Rocks.—About the line of the Bungonia-Windellama-Mayfield road a considerable change in the rocks and in the appearance of the landscape is noticed. The generally barren and rough topography towards the east gives place to smoother undulations extending westward towards the Shoalhaven divide on that side. The streams flow in wide, gentle valleys, which are constricted where bands of harder rocks cross them.

Commencing from the east, we find a series of shales (partly altered to slate) and sandstones. On Windellama Creek, to the north-west of Minshull Trig. station, for instance, a fine-grained brown micaceous sandstone is found, which may be noted again on Jacqua Creek some 15 miles to the north-north-east, near Leakfield Trig. station. In this part a considerable folding is in evidence, but proceeding westward a more uniform westerly dip is noticed, which varies from 30 to 90 degrees. Shales, fine sandstones and more occasional quartzites form the bulk of the rocks, and limestones have been found at intervals. Of the latter, some have been identified as of Devonian age, whilst those towards the eastern side are set down as Silurian (Carne and Jones, *Geol. Surv. N.S.W., Min. Resources*, No. 25, 1919). The eastern limestone at Windellama beside the Bungonia-Mayfield road would appear to be a continuation of the beds at Bungonia. The strike of the former is 30 to 35 degrees east of north, and they swing over to meet the meridional strike of the Bungonia beds towards Inverary Park. The chances are,

then, that a belt of Silurian strata occurs over the Ordovician, but the fact would not appear to have any considerable physiographic importance.

Towards the west of the area, hardened sandstones and quartzites have offered considerable resistance to erosion, with the result that a series of monadnocks is found near the western divide, of which the most prominent points are occupied by the Trig. stations of Percy (2,723 feet), Bullamelita (2,586 feet), and Jacqua (2,433 feet). Between the first-named and the remainder the divide passes over a wide col (Text-fig. 3), part of which has been covered by Tertiary basalt. Further to the west, very considerable erosion of softer strata has led to the formation of the plains of Lake Bathurst and Goulburn, which have the heights west of Mulwaree Creek as a western boundary.



Text-fig. 2.—Profiles across the Shoalhaven Plain. The lines are shown on Plate xiii. i. Includes residuals and the higher northern section. ii. Includes the northern divide of Windellama Creek and part of the southern divide of Nerrimunga Creek. iii. Shows the lower southern section in the region of greatest stream activity. Tertiary basalts and bauxites are indicated. Vertical exaggeration = 8·8.

Thus the western part of the area consists of rocks which are soft or only of a moderate resistance to erosion, varied in the west by harder strata. A general westerly dip of the order of 45 degrees has inhibited the formation of pronounced asymmetrical surface features, and extensive weathering, apparently carried on over a long period of time, has resulted in the accumulation of a thick layer of rock waste on the gentler slopes, and the general breaking up of the harder rocks of which the hills and ridges are composed.

c. Surface Deposits and Residues.—The effects of late Tertiary vulcanicity may be observed in parts of this area, and take the form of local basalt flows, dykes, bauxite deposits and surface beds of contact quartzite. Of the first-named, there

are four areas of some size (Plate xiii), the lava having generally been poured into shallow valleys on surfaces of low relief. Dykes are exposed principally in the gorges, the most notable being in the neighbourhood of Jerralong Trig. station, where the weathering basalt gives smooth slopes to the river (Plate xii).

A number of the deposits of pisolitic bauxite occur on hills away from any known basalt flows, and the most striking occurrences near the Bungonia-Mayfield road stand up as mesas of small extent (Text-fig. 3). Other occurrences are on the top of or beside basalt flows, examples being found on the Goulburn-Windellama road and above Jacqua Creek. Other small occurrences besides those marked on the map may exist, as the country on which they might occur is forested, and the deposits may occupy small areas on the bushy ridges. The height above sea-level of those observed agrees with the limits of basaltic occurrences, varying from 2,050 to 2,150 feet. Their physiographic value lies in giving a clue to the amount of erosion which has occurred in adjacent stream beds since their formation (Text-fig. 3), and the occurrence of bauxite deposits in close proximity at different elevations on the northern divide of Windellama Creek probably indicates that all are not of precisely the same age of formation.

In considering other surface deposits, mention may again be made of the thick mantle of rock waste found in most parts of the area. There are also water-borne deposits of considerable physiographic significance occurring within definite vertical limits in the eastern part of the area, and on the higher levels of that part of the tableland there are drift sands and contact quartzites.

Clays are found to a depth of a hundred feet or more in the drainage areas of Jerralong and the southern Spring Creek. They are whiter and more pure towards the lower limits, whilst the upper layers are impregnated with iron oxides and even contain layers of ironstone. These clays lie between ridges of sandstone whose joint planes and fractures have been indurated by a secondary deposit of limonite. The clays have been considerably eroded to form valleys of a rounded section (Text-fig. 2; Plate xii). The clays are derived from weathering *in situ*, and in part are covered by drifts of sand.

The sand drifts are found to the east and south-east of Nadgigomar Creek and in the vicinity of Jerralong Trig. station, where they comprise the drift marked by lighter dots on the map, Plate xiii. The sands are white or grey, depending on the amount of vegetable matter which they contain, and consist of angular quartz fragments at a general altitude of 2,000 feet, although in places there is a considerable thickness (Text-fig. 4). Similar stretches of sand extend southward past Oallen ford, on the Windellama-Nerriga road, and in the present case the derivation might have been from south or west. Associated with a sandy surface about the 2,000-foot level is a series of glassy grey contact quartzites, the principal localities being shown in Plate xiii. Dr. W. R. Browne very kindly examined some of this material under the microscope, and reports it to be identical with the quartzites developed at the contact of late Tertiary basalts at Tallong, and undoubtedly of a similar origin. Further reference is made to it later in the paper.

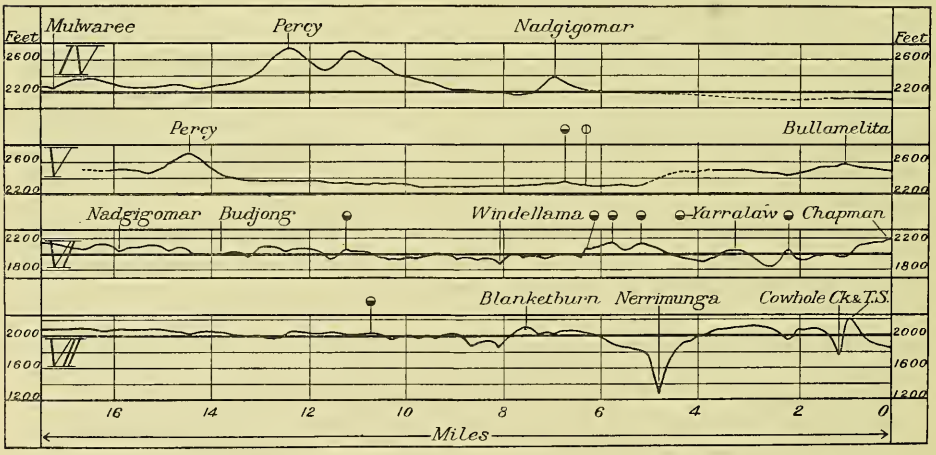
Deposits of surface grit and conglomerate are found extensively over the eastern part of the area, and where the occurrences are of any magnitude horizontal bedding is readily noticed. In the Inverary sector there is a thickness of 220 feet of conglomerate, sandstone, sandy shale and grit overlain by basalt; at Yarralaw Trig. station a thickness of 50 (?) feet of grit is overlain by bauxite; in the drainage areas of Windellama and Nerrimunga Creeks ferruginous grits and

conglomerates are widely scattered about the 2,000-foot level, whilst pebbles of grey quartzite and white reef-quartz are found in the neighbourhood of Manton Mine and Black Springs Creek. All of these are associated with the uplands, and their position on a highly-developed surface of erosion or peneplain, together with the position of some above deep gorges, puts them back definitely to the pre-canyon period. The actual or implied association with late Tertiary basalts gives much of this surface material a late Tertiary age at the latest.

In addition to these deposits, channels filled with stream drift occur to the east of the area. On account of their physiographic importance these can be considered in some detail when the nature of the Shoalhaven Plain is dealt with.

Topography and Physiography.

a. The Inverary Sector (Text-figs. 2 and 3; Plate xii).—The strip of country lying to the north of Inverary Creek consists essentially of two levels. The western portion rises above 2,100 feet, the highest points being the Trig. stations of Leakfield (2,191 feet), Chapman (2,204), Cowhole (2,204) and Inverary (2,164). The points rise above a dissected plain, and the three first-named owe their elevation to the more resistant character of the sandstones of which they are composed. Inverary is on a thin local basalt flow, whose maximum thickness does not much exceed 100 feet. The flow filling an ancient valley near Chapman Trig. is of a rather similar thickness.



Text-fig. 3.—Profiles of the Divides and the Shoalhaven Plain. The lines are shown on Plate xiii. iv. Extends WNW. to Mulwaree Creek and Tarago, and embraces the southern divide. v. Shows the western divide. vi and vii are longitudinal profiles of the Shoalhaven Plain. Tertiary basalts and bauxites are indicated. Vertical exaggeration = 8·8.

An outlying effect of the Inverary flow is a bauxite knoll to the north of Cowhole Trig. at 2,140 feet. According to the report of local miners, the bauxite is more than a surface capping, but the mesa structure indicates a previous higher level for the surrounding country. Hollows in the contorted strata near Cowhole Creek are filled by horizontal conglomerate, grit, soft sandstone and shale. The lowest of these beds are at 1,900 feet, and the highest rise to 2,150 (?) feet,

the best exposures occurring on Cowhole Creek and to the north of Washedaway Creek. In the former case, the beds are of light brown pebble conglomerate containing pebbles of quartz and quartzite up to 12 inches in diameter, and associated with light sandstone. The thickness of the phase is 40 feet, and the conglomerate is hard and massive. Above this are beds of friable sandstone and shale, the whole being overlain in part by the Inverary Park basalt. Pebbly clays containing fossil leaves have been found during mining operations under the conglomerate, and there is a strong probability of the beds being of late Tertiary age.

On Washedaway Creek the pebbles of the conglomerate are smaller, and it exists as a massive deposit between 1,980 and 2,000 feet. It is strongly impregnated with iron oxide, which gives a brownish or reddish appearance on weathering. Here again the shafts of alluvial miners have penetrated the clay below the conglomerate, but one does not notice pebbles in the dumps, although pebbles of much-decomposed porphyry are included in the Cowhole Creek clays. These beds contrast with the strata at the base of the Permian Upper Marine Series, which occur to the east of the river at an elevation of 2,300 feet. The latter are white or light-grey in colour, and contain rounded pieces of quartzite, quartz-schist, porphyry and slate set in a fine white matrix. The base rests on unweathered quartzites, sandstones and slates, and has an altogether different appearance from the sediments about the Inverary sector. Altogether there seems to be a clear differentiation between the two.

The second unit of the sector consists of a dissected terrace above the Shoalhaven gorge. It is cut across by Cowhole Trig. ridge, to the north of which is a dissected plain at 1,900 feet drained by the northern Spring Creek. To the south of the ridge the plain is somewhat higher, but falls from 2,100 feet on the west to 1,850 feet above the Shoalhaven gorge immediately south of the mouth of Cowhole Creek. This tract forms an essentially level plain cut across by the level valley of Washedaway Creek flowing 200 feet below its surface, and by the steeper, narrower gorge of Cowhole Creek, whose sides are almost precipitous (Text-fig. 3). The plain surface towards the river in this southern part is strewn with quartz gravel and pebbles between 1,940 and 1,980 feet, whilst ferruginous conglomerate overlooks the junction of Cowhole Creek with the river from 1,850 feet. Much of this material has been worked for gold, of which a little has been won, but it is simply a surface screening dominated from the east by the higher land across the river (Plate xii), and overlooked by Cowhole Trig. and the higher country to the west.

Thus we find a higher erosion level rising to 2,200 feet, whilst the newer—but still pre-canyon—level is from 1,850 to 2,000 feet. A considerable thickness of horizontal material exists towards the west, but it thins out to a mere screening which covers parts towards the east. It would appear that the lower levels have been cleared of the greater part of the newer material deposited upon them, as the Inverary Park beds have been considerably eroded on their eastern face, and the incoherent material which forms the greater part of such deposits on the tablelands offers no great resistance to erosion. An ancient erosional level based on or below 1,850 feet is indicated, and the basalts preserve a surface—partly of erosion and partly of deposition—at 2,060 feet.

b. The Shoalhaven River.—The general features of this stream have been described in the first paper of the series. Coming upstream from the junction with

Bungonia Creek, a gentle grade is followed through the "block-up", which lies below the mouth of the northern Spring Creek. Here the sides of the gorge rise sheer from the water's edge, and the whole space between them is occupied by a deep river. Above this point the river has moved laterally in places, one result being the abandonment of part of its old channel on the western side above Cowhole Creek, the former section now forming a lagoon, from which the waters of the river are diverted by a great bar of quartzite except in times of high flood. In places the flood terrace is up to 200 yards wide, and is covered with boulders, amongst which Casuarinas grow. Periodical floods destroy these, so only young trees are seen in such places. In other parts both sides of the gorge close in, making it almost impassable. At the mouth of Nerrimunga Creek there is a flood platform of scoured grano-diorite just above the level of the river, which is here interrupted by rapids. The tributary stream has carried huge blocks of igneous rock to the edge of the platform, one piece containing 180 cubic feet, but normally its volume is quite small, and it ceases to flow at times during the hottest months.

Above this point a uniform rise continues; basalt dykes cross the river near Jerralong Trig. station and further upstream (Plate xii), and still proceeding southward there is a steeper section with long series of rapids which lead to the gentler gullies of the tableland about Oallen ford.

The fall line of the tributary streams depends largely upon their catchment area, and only in the cases of Nerrimunga, Cowhole and the northern Spring Creeks, are the tributary gorges of any length when compared with the lengths of the respective streams which have eroded them.

c. Jacqua Creek.—This stream heads on part of the higher section of the western divide about 2,500 feet, and also on the basalt flow on the Goulburn-Windellama road at 2,300 feet. Its valleys are mature to their heads, and the stream itself shows well developed meanders and an old profile (Plate xiii). The wider bends enclose areas of level land which comprise a good deal of alluvium and hill-wash resting on pebbles. Passing the second area of basalt the valley widens out until the Bungonia-Mayfield road is reached, where the stream flats attain a width of 600 to 700 yards.

The presence of a bauxite capping on either side of the valley about 2,050 feet shows the extent of more recent erosion in the formation of this broad valley, whose floor is 200 feet below the bauxite. A contributing factor to this result has been the soft nature of the clayey rocks in which the wider parts are found. Proceeding, there is a great turn southward past Leakfield Trig. station. The stream flats have been left, and the stream is slightly entrenched in an undulating surface. A tributary valley in granite to the east of the Trig. station is broad, but it is limited on the east by rough sandstone and chert ridges and in this section the stream falls into a gorge, which deepens steadily to a depth of 500 feet at the junction of the stream with Nerrimunga Creek.

Between Jacqua and Nerrimunga Creeks and Leake's Gully the rough strike ridges persist, although they rise little above the smoother plain of the district, their highest points falling short of 2,100 feet (Text-fig. 3). Glassy contact quartzite occurs on the surface about 1,870 feet, to the north of Leake's Gully, its horizon here being 200 feet below the highest point on the ridges. These are considerably dissected by the short lateral and transverse streams typical of such country, but the valleys of such tributaries as that in Leake's Gully enter

Nerrimunga Creek above the fall line, their junctions are accordant, and the lower parts of their courses more gentle than the upper, which fall sharply from four linear ridges.

Between Jacqua and Windellama Creeks the dividing ridge is broad with slight rises, and gullies fall gently to the main valleys. This part follows the local strike, and consists of sandstones. In part it appears to be a continuation of the Jacqua Trig. ridge, and the hill on which Percy Trig. is situated may be an extension of the same line, although this is not certain, as the intervening plain is level and deeply weathered.

d. Windellama Creek.—This stream flows from the western divide through a broad, mature valley to Windellama. Wide, shallow tributary valleys come in from the northern side, whilst a gentle concave plain falls to it from the south. After crossing the limestone near the Windellama-Mayfield road, the stream passes through a trench 100 feet deep, but emerges into an undulating valley which is followed until the meanders are reached near Minshull Trig. station. Then the stream swings against bluffs of fine brown sandstone, whilst some of the bends enclose level plains. At the junction with Nadgigomar Creek at 1,800 feet a sharp trench exists, and marks the end of Windellama Creek proper, the combined stream being known as Nerrimunga Creek.

A feature of some interest exists by the roadside at Windellama, where a light grey sandstone associated with the limestone is found to have been silicified to a glassy quartzite. This follows the strike of the sandstone, and the lower limit of the altered zone is found by the roadside at 1,960 feet. The alteration was doubtless effected from a slightly higher level, and probably represents one result of the late Tertiary lava flows.

e. Budjong Creek.—This is, perhaps, the most interesting stream of the Nerrimunga drainage system, as its drainage area embraces the most varied topography. It rises in the hardened sandstones at Percy Trig. station, and flows for a short distance over gently-falling plains about 2,300 feet. Here it is a strike stream, but passing eastward from the influence of the high country, its course lies through a mature valley, where it is joined by Conner's Creek (the first from the left), about 2,000 feet, the latter also coming from a mature landscape. The deeply weathered and gentle slopes about this junction are smooth and clear and of a clayey nature, but near the Windellama-Mayfield road the valley narrows as it crosses harder sandstone and quartzite, and a bank on the left side rises 100 feet above the stream.

Passing the road at 1,930 feet, these conditions of topography continue into slates and sandstones, with very gentle slopes on the right side of the stream lying opposite the higher left bank. Above the junction with Nadgigomar Creek is a great "S" bend representing a somewhat incised meander. Against the first part of the "S" at 1,850 feet there is a low divide to the north only 40 feet above the stream; this divide and the slightly higher ridge continuing eastward are covered with pebbles, which have been cemented on the higher levels to form a ferruginous conglomerate, and probably represent Tertiary drift with no immediate connection with the modern stream. There are also occasional patches of glassy contact quartzite on this ridge, but more notable occurrences are found northward across the next small stream, where they occur about the 2,000-foot level.

The second part of the "S" encloses an ironstone knoll rising to 1,970 feet, but across the stream a gentle plain is lower. Budjong Creek is swinging

against the outer bends and is removing a flood terrace some 15 feet above summer water level. This alluvium rests on a soft planed-off terrace of sandstone and slate. Looking up the valley from the eminence referred to, it is seen to be broad and to lie very little below the level of the eastward-falling plain, which rises evenly on to the low western divide to the north-east of Percy Trig. (Text-fig. 2). Further east the ridges show a very even skyline from 2,000 to 2,050 feet, although a false appearance of height is given by the slopes leading up from Nadgigomar Creek. Budjong Creek falls into Nadgigomar Creek through an undulating valley.

f. Nadgigomar Creek.—The head of this stream is in the hills near Percy Trig., and its upper course lies in an early mature valley down the slopes. On approaching the Windellama-Mayfield road the valley widens, and more extensive alluvial flats up to 300 yards in width appear. Continuing downstream, the creek is found to flow with a gentle fall from 100 to 150 feet below the surface of the plain. This section is found in more resistant rocks than is Budjong Creek, so the valley is narrower and the flats more restricted. Gentle slopes and occasional wide tributary gullies lead down from the adjacent level plain on either side.

Wider alluvial flats are found above the Nerriga road up to the northward bend, but below the road the higher plain again closes in, and the valley narrows. In this section the grade is slight, and an old dam built for a mining water supply still holds back a considerable body of water. At the dam site an old channel has been exposed by recent erosion, and Tertiary quartzite is found as low as 1,910 feet, apparently transgressing the drift area (Text-fig. 4). The eastern ridges continue to rise from the water's edge, but near the dam on the west is an extensive level patch of sand drift.

The gentle fall of the stream continues, and once again the higher plain approaches from the west, to retreat in a series of gentle undulations as Budjong Creek is approached. The eastern ridges are also considerably eroded. Tertiary quartzite continues along the valley at intervals, generally being 50 feet above the modern stream, and the junction of Budjong Creek is marked by flats at 1,850 feet which contain rounded pieces of this material. Below here the valley again narrows in sympathy with harder strata, although the grade is still slight.

Passing the eastward road from Windellama and turning westward towards Minshull Trig., the left side is fairly steep and the right, though much gentler, is sandy and very barren. The trench at the junction with Windellama Creek has already been noticed, but immediately below the junction on the right side a limited flood terrace is found at 1,810 feet—some 15 feet above the stream. From the grade of the stream and the topography of the valley which it has eroded, it will be seen that a mature valley has been carved in a plain surface which falls gently eastward, the width of the valley and the gradient of its sides having been conditioned by the resistance to erosion of the strata concerned.

g. Nerrimunga Creek.—The course of the main stream falls easily and naturally into two sections according to its gradient (Plate xiii). For the first 4½ miles the stream flows in a trench 200 feet deep cut in a sensibly level stretch of land. For the greater part of this distance the creek is wide and deep, but the slight fall between reaches is marked by rocky stretches of channel. At the junctions with small tributaries there are restricted areas of undulating valley topography, but elsewhere the sides of the valley are steep, as the tributaries have selected the softer strata in eroding their courses, whilst resistant meta-

morphic rocks occupy the intervening sections. Below Leake's Gully the sides close in notably and are precipitous in places, but the stream flows gently in a channel up to 40 yards wide until the steeper fall is commenced.

When this event occurs, the trench is left and a characteristic "V"-shaped gorge entered, through which the stream falls uniformly to the Shoalhaven. The maximum depth of the gorge is 1,200 feet, and it is marked by deeply entrenched meanders. Slopes on the concave sides are steep and, as the rocks are highly inclined and well jointed, loose scree is common and landslides occur. The convex sides fall towards the creek as longer and gentler peninsulas. The only tributary gorge of any length is that of Jacqua Creek, which flows over bars of massive grey quartzite in entering the main stream.

Above the gorge there are terraces between 1,800 and 1,900 feet above sea-level, on which ferruginous grit, sand, Tertiary contact quartzite and water-worn pebbles are found. Away from this irregular terrace—which is not developed near the river—the land rises to rough ridges on the north-west, but is gentler to the south, where sandstones and softer slates are more in evidence.

Taking Nerrimunga Creek and its tributaries as a whole, certain general features stand out clearly. The streams have cut shallow, mature valleys in an upland plain surface, and have taken advantage of the softer country west of the chert belt in widening their valleys. In this section the rocks have been notably weathered and decomposed in harmony with the general appearance of maturity, but the more siliceous strata further east, although forming a lower surface, contain the rougher and narrower valleys. The most notable of these is the trench in which the first portion of Nerrimunga Creek flows. Differential erosion in the sloping plain is thus important.

The upland parts of the streams, down to 1,700 feet, are beautifully graded, and show profiles characteristic of maturity. The smooth profiles of the lower part of Nerrimunga Creek and the portion of the Shoalhaven involved are characteristic of powerful streams cutting through highly-inclined rocks. Individual waterfalls and cataracts are small, but there is a definite break of slope in the profiles below 1,700 feet.

Parts of three cycles of erosion are shown. The oldest is a small section at 2,300 feet at the head of Budjong Creek; then comes the most extensive, which has been carried to maturity over the area and is based about 1,700 feet. The latest and, at present the most active, is controlled by the existing grade of the river, but the head of erosion is only advancing upstream very slowly on account of the hard inclined rocks being encountered.

All of the larger streams show well developed meanders. Above the junction of Windellama and Nadgigomar Creeks it may be taken as a general rule that present-day conditions favour the extension of the meanders, which are being actively enlarged in many cases. Below this junction, however, the sides of the trench into which the main stream flows are both uniformly steep, especially below Leake's Gully, and no important lateral movement is indicated since the stream began to entrench itself in the terrace above 1,800 feet. The occurrence of pebbles and drift over this higher level demonstrate considerable lateral movement before the erosion of the trench and the gorge below it, so it appears certain that the meanders of Nerrimunga Creek have been inherited from this level with but little enlargement or alteration in plan, although the sloping ridges enclosed by the meanders of the gorge section do not preclude the possibility of lateral extension in the process of downcutting, and a certain amount of which is to be expected.

The commencement of the meanders apparently post-dates the surface deposits of the tableland.

The persistence of old stream lines is indicated by the correspondence of the drift and Tertiary quartzite with the hollows in which modern stream valleys are found. This is especially the case with Nadgigomar and Nerrimunga Creeks, whose general directions are largely pre-basaltic in age, and bear a close relationship to the hard chert ridges. In the case of Jacqua Creek, the presence of grit at Yarralaw Trig. station, together with the associated and neighbouring bauxite deposits all lying within the boundaries of the main valley (although well above the stream), indicate a stable outline for that creek also. The basalt-filled hollow near Chapman Trig. with a base about 2,050 feet corresponds with the bauxites of the valley at 2,050 feet, and may possibly indicate a former stream line leading north-eastward towards Bungonia Creek. The steep fall of the corresponding tributary to Bungonia Creek is unfavourable to the suggestion, which is not supported by the meandering stream line towards Nerrimunga Creek cut indifferently through soft and hard strata.

Perhaps the most significant fact disclosed in the study of these streams is the general mature erosion of the upland section to a local base level somewhat below 1,700 feet above sea-level. If the upland profile of Nerrimunga Creek be continued, it will reach the Shoalhaven about 1,650 feet, which may be taken as the downward limit of erosion in the area previous to the new cycle resulting in the erosion of the canyons. As we shall see presently, the fact is by no means isolated.

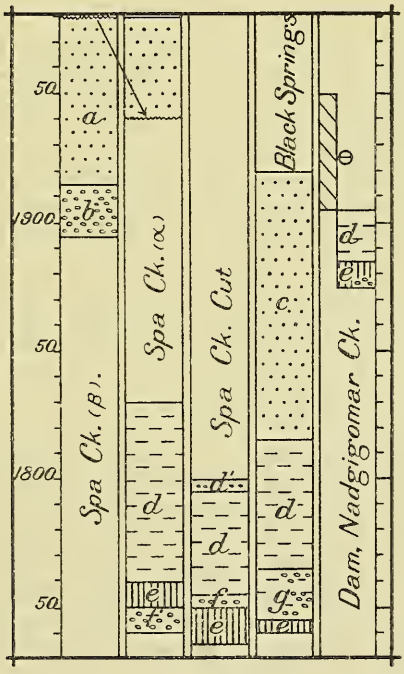
Land Forms.

a. The Residuals (Text-figs. 2 and 3).—The existence of old residuals on the western divide has already been noticed and explained. The massive quartzites noted in the first paper of this series are not developed to any extent in this area, so the high ridges become less in extent and more disconnected as one comes southward from the Bungonia district, until such residuals as Percy and the isolated double hill which forms Nadgigomar Trig. station consist of sandstones which have been locally hardened as a result of igneous intrusions. Even in the cases of the highest points, the slopes leading up to them are not so steep as those found in the residual ridges west of Bungonia, and a great basalt-filled col occurs on the western divide. Towards the east of the area there are several points rising to 2,200 feet, but these would appear to represent locally unweathered rocks which stand up a little above the general even skyline about 2,000 feet. Notable relics of ancient cycles of erosion are virtually confined to the west of the area, and are not extensive.

b. The Shoalhaven Plain.—On the other hand, the Shoalhaven Plain has become a far more important feature than it was further north. Towards the east of the area it has a great extent between the defined limits and 2,100 feet. Towards the west of the area it rises gently, and part of the country in the Inverary sector also rises above the defined upper limit. From the stream grades and general topography (Text-figs. 2 and 3; Plate xiii), it may be inferred that the lower parts of this plain have been produced as the result of normal erosion acting on somewhat higher land which resembled the lower parts of the western divides in altitude. The evidence of a dissected plain was noticed in the discussion of the streams, and the fact stands out clearly from the profiles. In addition the drift, Tertiary quartzite and bauxite deposits all occur within definite limits and from

50 to 200 feet as a general rule above the modern stream channels. Of the many examples observed and charted, the lowest limits of the tableland drift are about 1,850 feet, above Nerrimunga Creek, whilst the general run of them away from this lineament is around 2,000 feet. The quartzites occur between 1,900 and 2,050 feet, with a predominance of those towards the upper limit, whilst the bauxites are found about 2,050 feet, with exceptions rising to 2,150 feet. In addition, the base of the Chapman, Inverary and Jacqua Creek basalts is about 2,050 feet. It may therefore be asserted that the Shoalhaven Plain forms a definite surface of erosion and later deposition at a general level of the order of 2,000 feet above sea-level, and that mature valleys have been incised to 200 feet in this surface.

There is, however, another factor to aid in the elucidation of the physiography of this upland surface. Above the Shoalhaven River, beds of drift containing a little fine gold have been extensively cut away in the process of sluicing, and fine sections of them are now exposed (Text-fig. 4). Mention has been made of the old stream channel exposed near the dam on Nadgigomar Creek and, with the exception of elevation, it might serve as a typical example. Alluvial deposits lie on highly weathered and softened slates and sandstones crossed by beds of unweathered chert, and consist of ferruginous conglomerate overlain by black, laminated peaty clay containing old tree trunks in hollows altered to lignite. Overlying this again is clear white quartz gravel cemented loosely by white clay,



Text-fig. 4.—Sections of late Tertiary Drift. *a*, sand and small pebbles; *b*, large pebbles and conglomerate; *c*, sand; *d'*, surface pebble drift; *d*, quartz gravel and clay; *e*, carbonaceous clay, peat and lignite; *f*, ferruginous conglomerate and coarse gravels; *g*, quartz gravel and pebble beds. See also Plate xii.

and drifted over by brown hill-wash. The wash is roughly stratified and, although Tertiary contact quartzite is present in quantity at a slightly higher level, it cannot be definitely asserted that it overlies the alluvial deposits.

Turning to the east of the area, a similar kind of deposit is found at Black Springs Creek, where a cut some 600 yards long and up to 200 yards wide has been made in it. But whereas the material at the dam has a lower limit of 1,870 feet, that at Black Springs is found as low as 1,730 to 1,740 feet, and lies in a valley excavated in the tableland rocks. Above the finer quartz drift a zone of sand is entered which persists above the head of the workings at 1,820 feet right to the head of the stream. Passing northward over the sandy upland, shafts sunk for short distances at intervals reveal small water-worn pebbles in the sand, and small gullies falling to Spa Creek are eroded in this material.

Spa Creek leaves the line of the deposit in its fall towards the cliffs overlooking the Shoalhaven, but a cut 300 yards long gives a complete section of them. Again the base is about 1,730 feet above sea-level, and the thickness of the deposit in the main cut is 70 feet. The loose pebbles of Black Springs are here replaced by solid ferruginous conglomerate, and the relative position of the peaty clays is found to change. Still continuing northward, a minor cut shows the quartz drift giving place to roughly stratified white clays towards the western section, whilst still further north the deep ground is left and a bed of conglomerate at a much higher level is noticed, again overlain by sand. As with the surface conglomerates of the Shoalhaven Plain, it is likely that the ferruginous cement was derived from the underlying rocks and brought to the (then) surface in solution. Pebbles overlying the deep ground would not be liable to such action, and would soon be swept away in subsequent processes of erosion. The higher conglomerate is also drifted over with white or light grey sand. The main deposit at Spa Creek resembles the occurrence at Black Springs in lying in a valley eroded in the tableland rocks which, for the greater part, form a ridge between the drift area and the gorge of the river, but northward of the place where the creek plunges into the gorge, the stream deposits have been cut off by the gorge side, and overlook the river directly.

The old channel at Nadgigomar dam may be dismissed with one further comment—it gives a further proof of the permanency of that particular stream line, but the occurrence is local and the vertical range affected is not great. On the other hand, the more easterly occurrences involve questions of greater importance, as they cover a vertical range of 300 feet, and occur on the edge of the major canyon of the region.

One of their most striking features is noted more especially at Black Springs, where huge slabs of glassy contact quartzite occur in the basal pebbles. These include fragments of chert and pebbles, and with the exception of the contained pebbles, they are similar to the quartzites at Nadgigomar dam, from which Browne's determination was made. Some of these fragments are up to 4 feet long by 3 feet wide by 1 foot thick, and the edges have been smoothed and rounded. Smaller worn pieces of the fine uniform quartzite are also found here, and in the loose drift above the main cut at Spa Creek. It seems fairly definite that this material is of late Tertiary age, and is from basalt contacts, so the drift areas are newer than some phases of the basalts, at least.

As regards other pebbles a variety of quartz and quartzites is found, together with much-weathered porphyries, and possibly some granite. In shape they vary from subangular to ellipsoidal, and in size from three inches to more than a foot

in (major) diameter. The peaty clays associated with them contain abundant broken plant material, but no good specimens.

It is now possible to sum up some of the relationships of the drift. It has been deposited in a valley—or in valleys—eroded to a modern height of 1,730 feet, and general conditions of relative stillness are indicated in the streams or lake into which the material was brought. At times more vigorous currents brought in pebbles, but the general accumulation was of small material, and in the last stages, when the water was spread out over the widest area, sand derived from the higher levels of the watersheds concerned formed the bulk of the material. Conditions were equivalent to continued subsidence, and the total extent was of the order of 300 feet. Conditions of a rather similar nature have already been noted in the Inverary sector, but extending definitely 50 feet higher, and possibly a little more.

This leaves two major questions—the cause of sedimentation and the origin of the channel or channels in which the deposit is found. For the present, no attempt will be made to answer the first of these, but the second may be considered.

The most likely explanation was propounded to the writer by Mr. G. McKane, who suggested that the Black Springs and Spa deposits lie in a continuous channel which was an earlier course of the Shoalhaven. He instanced the facts that sluicing for gold had disclosed a "run" of gold near the base of the drift which continues towards the modern watersheds without any appreciable change of level; that the pebbles of porphyry in the Spa deposits are, so far as is known, not derivable from the catchment area of that stream, although occurring in abundance further south, and that the size of the pebbles in the drift is more suggestive of a large stream than one such as Black Springs Creek. To the latter one might add that there is nothing to show the quartz pebbles or gold as being of immediately local origin. He also correlated the different exposures, and inferred the constant height of their base—a supposition verified by observation.

Physiographically, the suggestion is sound. The base of the deposits is at a constant level as far as it is exposed, and the respective exposures are in wide channels on the tableland. Even such a powerful stream as Nerrimunga Creek has eroded a valley of much less width about the altitude of 1,700 feet, and one of the features of this drifted valley is the width of its floor. Sedimentation also proceeded above 2,000 feet, which would have left the Shoalhaven free to choose a course over a wide stretch of country (Plates xii–xiii), as the superior heights about Jerralong Trig. station are simply local knolls. Once such a course were chosen, the renewal of downcutting would scarcely introduce factors likely to lead to considerable further change, for although the drift would be easily channelled, the deeply-weathered clays derived from the country rocks would only offer slight resistance to a powerful stream. In any case, the two minor streams now existing in the drifted area have not breached the sands of their divide, and the country immediately south-west of Jerralong Trig. is amongst the clay land.

Thus it appears that, under special circumstances, the Shoalhaven adopted a new course after the sedimentation was completed, but had previously eroded a valley down to 1,730 feet. In any case this was the lowest level reached before the deposition of the sediments, and it may be correlated with the upland course of Nerrimunga Creek, which is based about 1,650 feet. In other words, the plain was developed about 2,000 feet (modern level), and valleys from 300 to 400 feet in depth were eroded in it. The course of the main stream was partially blocked to an increasing extent, leading to local sedimentation. About the same time

basalt was coming gently through fissures and was being poured out on the land surface, affecting the plain principally, and being associated with the upper limits of the sediments. The actual outpouring began prior to the filling of the deeper channels, and it is probable that the deposits of the higher levels about the junction of Windellama and Nadgigomar Creeks can be correlated with the highest stage observed in the neighbourhood of Spa and Black Springs Creeks, and with the deposits at similar altitudes in the Inverary sector. Thus the erosion of channels to the modern level of 1,700 feet, the outpouring of basalt and the process of sedimentation were, broadly speaking, contemporaneous, and all predated the erosion of the gorges.

c. Comparison with the Tallong-Bungonia Area.—The physiographic features of the two sections may be directly compared, as follows:

Age.	Tallong-Bungonia.	Nerrimunga Creek.
Ancient	High residuals.	High residuals.
Pre-basaltic ..	Residual level, Tallong, 2,400 feet.	Western divide, 2,400 feet.
Pre-basaltic ..	Peneplain level, 2,200 feet.	——
Pre-basaltic ..	Valleys and plains about 2,000 feet.	Shoalhaven Plain, about 2,000 feet.
Period of flows ..	Erosion of Caoura valley to 1,850 feet or lower.	Erosion of eastern channels to 1,700 feet.
Period of flows ..	? Pebbles and drift of uplands, 1,900 to 2,000 feet.	Drift and sediments, 1,730 to 2,050 feet. (Exception—Inverary Park to 2,150 feet.)
Post-basaltic ..	Mature valleys to 1,800 feet, deepening eastwards.	Erosion of drift—mature valleys of plain, and upper part of Nerrimunga Creek trench to 1,700 feet.
Post-basaltic ..	Erosion of gorges.	Erosion of gorges.

Reference has previously been made to the fact that the basalt-filled Caoura valley was eroded by a small tributary stream, whilst the Shoalhaven apparently flowed at a lower level (Part i), so there is no necessary discrepancy here. The highest of the sandstones at Inverary Park form a purely surface deposit a couple of feet thick in places, but this superficial character is not everywhere certain. The highest of the bedded deposits occur at 2,070 feet.

The connection between late Tertiary channels eroded to the modern level of 1,700 feet and the supposed river capture at Tallong above 2,080 feet is evident, as the surface concerned shows no bending or warping which could account for the downward displacement of the lower channels since the period of basalt flows. On this ground alone it would be legitimate to rule out the idea of capture since the erosion of those particular tableland valleys and, since they antedate the more modern uplift which allowed the erosion of the gorges, the suggested mechanism of capture is not allowable. Thus the conclusions of the first paper of the series are fully justified.

Soil and Water Supply.

Geology and physiography unite in determining the conditions of the soil and water supply. The soils fall into three definite classes: firstly, there are large areas of stony ground in the area, the more dissected siliceous rocks towards the east giving a surface of this type, whilst the higher ridges and divides towards the west are also composed of siliceous types which do not weather readily into soil. In the parts which have been subject to dissection, even over a small vertical range, the slopes are steep, so the general character of this class of country is very dry.

Secondly, there are areas where a considerable depth of clay is found on the surface, or the soils are of a clayey nature. These include much of the valley of Jacqua Creek and the gentler slopes of the valleys west of the Bungonia-Mayfield road, together with the basins of the southern Spring and Jerralong Creeks and the country immediately south-west of Jerralong Trig. station. Country of this type supports the small settlement of Windellama and, since its soil is richer in plant foods than that of the preceding class, it has a considerable value as pasture land, being used for sheep raising. The soil is naturally rather impervious so, with respect to their lengths and the areas which they drain, the streams are of small size and the flow of water even in Nerrimunga Creek is inconsiderable. All of the tributaries cease to flow during the hotter months, but the fact is somewhat offset by their mature form favouring the development of wide and deep reaches which retain water all the year round. In this respect the impervious nature of much of the ground is an advantage. By virtue of it, also, tanks and dams can be built to supply water to stock.

The third soil type comprises the sands and gravel of the drift areas, together with the sandy lands found to the east and south-east of Nadgigomar Creek. Water soaks into this ground readily, but is quickly given up to the local streams, leaving a generally dry surface which is covered with sparse forest and hardy vegetation. This land is of little economic value, but in the isolated case of Black Springs, where it overlies a more compact and impervious drift, a good storage ground for a permanent stream is provided. In general, however, the sandy and drift country is dry and poor.

Isolated areas of particularly rich soil are provided by the larger areas of basalt. In each case the weathering basalt gives excellent pasture land, and a little permanent water comes, in places, from springs under the basalt. These few patches form the best pasture land of the area; the valleys of Jacqua, Windellama and Budjong Creeks are fairly good in general, whilst parts of the valley of Nadgigomar Creek and of the clay region around the head of Jerralong Creek and by the Trig. station of that name are fair. Another isolated area of fairly good land is at Weiramunga Creek, overlooking the junction of Nerrimunga Creek with the river, but there is much almost useless land in the area, including the dissected portions. An exception to this latter remark is found on the western side of the Shoalhaven on either side of Jerralong Trig., where the steep, smooth side of the gorge, with a stiff soil from weathering basalt and slate, has been cleared, although bands of vegetation have been left across the slope in places and on the bottoms of depressions. These have an excellent effect in checking erosion, and provide a welcome contrast to the usual indiscriminate clearing only too frequently practised in such places.

Summing up, it may be said that half of this area is of little value on account of ruggedness or extremely poor soil. Some of this part carries a few sheep, whilst

the remainder of the country is used in sheep raising, and has the reputation of being free from disease and of growing clean wool. Conditions of soil and topography militate against a considerable permanent flow of the streams, but sufficient water is available for pastoral purposes.

Conclusion.

The features developed in the Tallong-Bungonia area are found to extend southward into the Nerrimunga Creek drainage area. The western residuals lose much of their extent, but the Shoalhaven Plain extends notably, and becomes even more important further south. Old channels filled with alluvial material are incised 300 to 400 feet below its general level. In all probability their age is late Tertiary, being the same as that of the basalts, and a similar but perhaps more modern channel eroded to the same level is found in the course of Nerrimunga Creek. The courses of this stream and of the Endrick River, further to the east, are most favourable for the development and preservation of such features, the streams being sufficiently powerful for the former, and yet not powerful enough to carve such notable gorges as that of the Shoalhaven. The physiographic history as developed in the first paper of the series and again outlined in this (see "The Shoalhaven Plain" section) is found to receive substantial support.

EXPLANATION OF PLATES XII-XIII.

Plate xii.

1. View eastward from Cowhole Trig. (2,204 feet), showing the dissected terrace falling to 1,850 feet. The higher country in the background is beyond the Shoalhaven gorge, and is the western scarp of Bulee Ridge. Touga West Trig. (2,409 feet) is the high bluff to the right of the big tree. 2. Hydraulic cut in Tertiary drift, Spa Creek. *x*, bedrock; *f*, conglomerate; *e*, carbonaceous clay; *d*, clay and quartz gravel. 3. The Shoalhaven Plain from Blanketburn Trig. (2,115 feet), looking SSE. The foreground shows erosion in surface clays. The Shoalhaven gorge is in the middle distance, and low on the central horizon is Currockbilly Range (3,700 feet), thirty miles distant. 4. The Shoalhaven River at Jerralong Trig. station, which is the hill to the right. The cleared slopes represent basalt dykes, whilst the high ground on that side is characteristic of a clayey surface, and forms part of the ridge separating the gorge from the Tertiary stream drifts of the tableland.

Plate xiii.

Map of the Nerrimunga Creek section of the Shoalhaven Valley. Form lines are shown in the uplands, and the line at 1,800 feet marks the general fall line to the steep gorges. Profile line iv extends to Tarago. B. Profiles of the principal streams. The sharp drop in Nadgigomar Creek represents the dam, and the part of the Shoalhaven River shown extends from Jerralong Creek to Bungonia Creek. For economy of space, the lower portion has been carried to the left. Vertical exaggeration = 17·6.